The Berkeley MEMS Particulate Matter Monitor

Chip-size micro-electro-mechanical sensors for particles in the air will provide inexpensive warning system to asthmatics, sense unhealthy air in cars and trucks, improve factory floor occupational health.

The MEMS Particle Monitor is a chip-size technology that senses and relays information by radio signal about particle concentration in the air. It can be mass-produced cheaply, and incorporated in any kind of stationary or mobile device—cell phones, vehicles, in homes and workplaces, and even on clothing.

It has been developed by Michael Apte and Lara Gundel and co-workers at the Lawrence Berkeley National Laboratory's Environmental Energy Technologies Division, and Richard White and Justin Black of the Berkeley Sensor and Actuator Center at UC Berkeley.

How It Works

The monitor determines the particulate mass deposited as a function of time on a micro-fabricated electronic resonant mass sensor (film bulk acoustic resonator, FBAR) coupled to a CMOS oscillator circuit chip. As the deposited mass of particulate matter increases, the resonator frequency decreases.

Thermophoresis is the principle used to cause particles to deposit on the mass sensor—a microscopic electrically powered resistive heater produces a thermal gradient in a gaseous medium that causes particles to deposit on the resonator.

The present prototype has a volume of 250 cm³, a mass of 0.114 kg, and a power consumption <100 mW. With some minor redesign, the monitor could be made considerably smaller and lighter. It is designed to be battery powered.

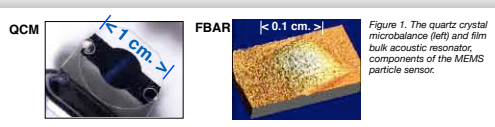

Figure 1. The quartz crystal microbalance (left) and film bulk acoustic resonator, components of the MEMS particle sensor.

Figure 2. Thermophoretic particle deposition.

Performance

Measurements made in an environmental chamber and in a residence in Berkeley showed excellent correlation of the monitor's response with that of standard test equipment for PM2.5 particles. The limit of detection (LOD) of the prototype design was found to be 18 $\mu g \cdot m^{-3}$. The results of initial design testing identified ways to reduce the LOD by a factor of 10.

Industry Interest

Another round of development is needed before the device can be commercialized. At least one major manufacturer has agreed to support this effort with in-kind support if additional venture capital becomes available.

Potential Applications

Asthmatics' warning system—Embedded in cell phones and other devices, the chip can sense levels of particles of concern to sensitive asthmatics. A population of particle sensing phones reporting via a cellular network can create real-time, graphical information of dirty air zones for asthmatics to avoid.

Vehicle unhealthy air warnings—Embedded in diesel-powered cars and trucks, and buses, it can trigger an alarm or control ventilation when the particle concentration of interior air becomes hazardous.

Factory floor health—Embedded in industrial facilities, in fume hoods, or on personal protective clothing, the MEMS particle sensor can trigger warnings when particle concentrations exceed OSHA standards.

Air quality monitoring—Air quality authorities can use networks of sensors to monitor the particulate concentration of air quality districts, and issue "Spare the Air" warnings in real-time.

Air quality and health research—Arrays of mobile particle sensors with cellular geo-positioning and communication capabilities can be used to improve population exposure estimates for critically needed environmental health research

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A U.S. DEPARTMENT OF ENERGY MULTI-PROGRAM SCIENTIFIC LABORATORY
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Environmental Energy Technologies Division

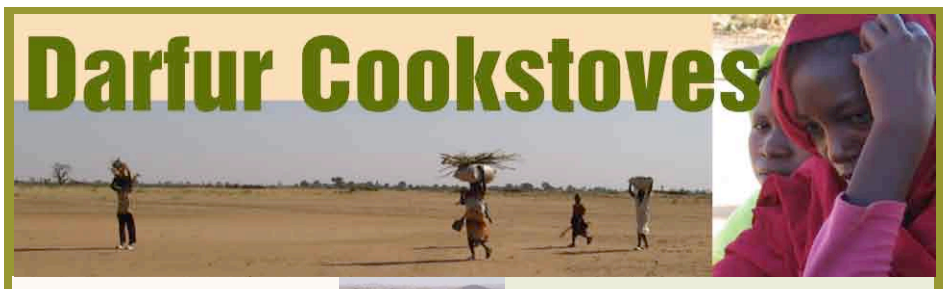
The mission of Berkeley Lab's Environmental Energy Technologies Division is to perform research and development leading to better energy technologies that reduce adverse energy-related environmental impacts. Our work increases the efficiency of energy use, reduces its environmental effects, provides the nation with environmental benefits, and helps developing nations achieve similar goals through technical advice.

BSAC Berkeley Sensor & Actuator Center

The Berkeley Sensor & Actuator Center conducts industry-relevant, interdisciplinary research on micro- and nano-scale sensors, moving mechanical elements, microfluidics, materials, and processes that take advantage of progress made in integrated circuit, bio, and polymer technologies.

www-bsac.eecs.berkeley.edu

Darfur Cookstoves



Reducing Rape and Mutilation For Darfur Refugees and Preventin Environmental Degradation With Fuel Efficient Stoves

Persecution of African Sudanese since 2003 has driven 2.2 million people, the majority of them women and children, into crowded camps scattered in arid areas, with low fuel wood productivity. Venturing outside these boundaries in search of fuel to cook their meals often ends in violence against camp inhabitants.

Lawrence Berkeley National Laboratory, the University of California, Berkeley, CHF International, and others are working to reduce the violence against people in these camps, and to improve their access to fuel-efficient stoves for preparing meals. Learn how you can help.

For more information see http://darfurstoves.lbl.gov

Almost all the Darfur refugees still cook on inefficient three-stone fires. As the surrounding region loses its fuel wood, women in the Darfur camps must travel even further to gather fuel—exposing them to greater risk. In late 2005, Berkeley Lab researchers visited the refugee camps in Darfur, and demonstrated that with a $10 metal stove and the training to use it:

- the fuel wood demand could be halved,
- women's trips to collect fuel wood would be reduced 50%, halving their exposure to risk in leaving the camps,
- pressure on the local environment is significantly reduced, allowing trees time to regenerate.

In 2006, a team of four UC Berkeley students under direction of Dr. Ashok Gadgil have

(1) Improved the efficiency of the metal stove further—nearly doubling it compared to the earlier model,

(2) made the stove mechanically stable to better suit Darfur cooking methods, and

(3) improved its performance in the presence of winds.

The improved stove was taken back to Darfur in July 2006, where it was extremely well received by women and men in the refugee camps.

CHF International, a U.S. non-profit, is Berkeley Lab's partner in the Darfur stoves project. They have raised funds from USAID´s Office of Foreign Disaster Assistance (OFDA) to cover part of the cost of this work.

The 2.2 million refugees need about 300,000 stoves.

Participants in the project include:
Ashok Gadgil, Christina Galitsky, Jeiwon Deputy—Environmental Energy Technologies Division
Pam Seidenman, of Technology Transfer Department, Lawrence Berkeley National Laboratory.
Susan Amrose – UC Berkeley Graduate student

Engineers without Borders – San Francisco Professional Chapter

In the 2005 Darfur visit, Ashok Gadgil and Christie Galitsky were accompanied by Mark Jacobs and Yoo-Mi Lee as participating guests of Berkeley Lab.

Susan Amrose, Charles Kirubi, Teddy Kisch, and Jesse Wao, students from UC Berkeley's Spring 2006 semester, worked on improving stove design, under direction of Ashok Gadgil.

Environmental Energy Technologies Division

Wireless Lighting Controls

THE PROBLEM

Nearly half the energy consumed by lighting systems in buildings is squandered because most commercial buildings do not use energy-saving lighting controls.

THE SOLUTION

Smart lighting products and wireless networks are emerging that allow lighting systems to be controlled without installing any additional control wiring.

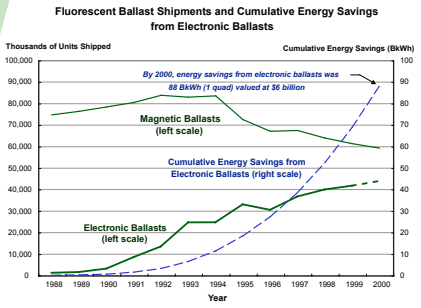
Lighting Control Strategies:
• Use available daylight • Vacancy detection
• On demand personal dimming • Demand response

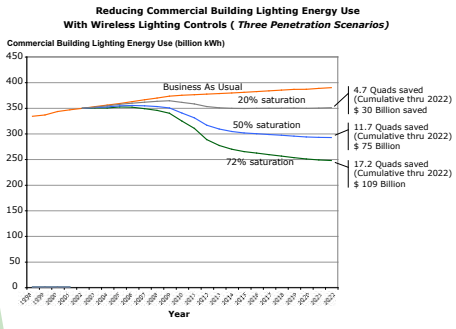
THE RESEARCH

LBNL has demonstrated that wireless lighting control systems can implement all lighting control strategies with acceptable system response time.

THE MARKET POTENTIAL FOR LIGHTING CONTROLS

- 60 billion square feet of commercial floorspace
- One billion lighting ballasts
- 250 million electrical boxes, switches, and sensors





THE NATIONAL ENERGY SAVINGS

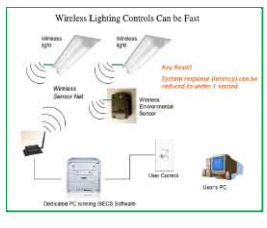
Estimated National Energy Savings from Wireless Lighting Controls Installed in U.S. Commercial Buildings

	Annual Energy Savings	Value of Annual Savings	Cumulative Energy Saved thru 2022	Value of Accumulated Savings thru 2022
Low Penetration	39 BKWh	$2.7 billion	4.7 Quads	$40 billion
High Penetration	142 BKWh	$10 billion	17.2 Quads	$109 billion

BENEFIT TO CALIFORNIA

Wireless lighting controls could reduce the annual energy costs for California office buildings, schools and retail stores by 3 billion kilowatt-hours. This would save California businesses $450 million in avoided energy costs each year while reducing greenhouse gas emissions, firming up the State's electricity grid, and improving the quality of building lighting systems.

Manufacturers of Wireless Lighting Products:
- ELB Electronics, Inc
- PowerWeb
- Philips Lighting



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ENERGY-EFFICIENCY STANDARDS FOR APPLIANCES

Lawrence Berkeley National Laboratory's Assistance to the Department of Energy

Congress mandated energy-efficiency standards for most major appliances sold in the U.S. in legislation passed in the 1970s, 80s and 90s. It designated the U.S. Department of Energy (DOE) to set these standards for 13 appliances, using a consultative process that involved all the stakeholders, from appliance manufacturers to non-governmental groups.

The Energy-Efficiency Standards Group in the Environmental Energy Technologies Division of Lawrence Berkeley National Laboratory became the primary technical consultant to DOE, providing engineering and economic analysis of the impacts of proposed standards.

The DOE appliance standards program is still ongoing. New standards for central air conditioners and heat pumps took effect in 2006 and new standards for clothes washers will become effective in 2007.

Appliance efficiency standards cover:

Refrigerators, freezers, central air conditioners, room air conditioners, clothes washers and dryers, dishwashers, water heaters, and gas furnaces.

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ENERGYGUIDE

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